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am conversant in the English language and I state that the following is a true translation to the best of my knowledge and belief of the International Application PCT/EP 03/ 06376 dated June 17, 2003.

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DISPLAY CELL, IN PARTICULAR LIQUID CRYSTAL CELL, OR PHOTOVOLTAIC CELL COMPRISING MEANS FOR CONNECTION TO AN ELECTRONIC CONTROL CIRCUIT

The present invention concerns a display device defining a volume for retaining a fluid such as a liquid crystal, and more generally, a sensitive material capable of changing its physical properties, particularly its optical properties, via the application of a voltage, or its electrical properties, via stress or radiation. In particular, the present invention concerns a display device of this type including means for connecting it to an electronic control circuit.

In its widest acceptance, a liquid crystal cell is essentially made up of a transparent front substrate and a back substrate that may also be transparent, or not transparent, these two substrates being joined and maintained at a constant distance from each other by a sealing frame, which defines a sealed volume for retaining the liquid crystal. Further, the front and back substrates each include, on their faces opposite each other, at least one electrode, these electrodes being intended to be connected to an electronic control circuit which, by the selective application of appropriate voltages to determined electrodes, enables the optical properties of the liquid crystals to be altered at the point of intersection of the electrodes concerned.

One constant problem in the field of manufacturing liquid crystal cells of the type described hereinbefore is raised by the connection means for setting up the electrical connection between the electrodes of the cell and the control circuit. One simple technique for accomplishing the electrical connection between the electrodes and the control circuit consists in staggering the substrates in relation to each other, so that one can access a flat part of the electrodes and thus easily form the connection on the surface thereby freed. However, such an arrangement of the substrates makes large-scale manufacture of the cells difficult, particular when the latter are circular, and it requires additional time-costly operations. The resulting cells are also of larger dimensions and thus difficult to house inside portable electronic objects of small dimensions such as a wristwatch.

Another solution to the aforementioned problem has been proposed by the Applicant in the International Patent Application published under no. WO 99/41638. There is known, in fact, from this Application, an electro-optical cell such as a liquid crystal cell, or an electrochemical photovoltaic cell, these cells each being formed of a transparent front substrate, a back substrate that may also be transparent or not, a sealing frame joining the two substrates and defining a volume for retaining, in a sealed manner, a photo-electrically or electro-optically active medium, the substrates including on their faces opposite each other at least one electrode. These cells differ

in that their electrodes are partially flush with the edge of the substrate on which they are deposited to define lateral electrical contact zones at the level of which right-angled shaped parts are added, which advantageously allow the electrical contact to be transferred to the back face of said cells.

Owing to these features, it is no longer necessary to stagger the two substrates of a cell to be able to establish the electrical connection between the electrodes of said cell and its control circuit, such that these substrates can be identical and arranged one overlapping the other. This thus results in great cell manufacturing simplicity, and thus to a considerable reduction in their cost price. Moreover, the space requirement of the cells is reduced, which facilitates the assembly thereof particularly in a wristwatch.

The solution described hereinbefore has, however, one drawback. In fact, the electrical contact parts, made of metal or a metal alloy that conducts electricity, form discrete elements that have to be bonded one after the other by means of a conductive adhesive onto the edge of the cell, at locations where the electrodes are flush with the edge of the substrate on which they are deposited. Such a manufacturing method, while relatively simple to implement in the case of an electrochemical photovoltaic cell which only comprises two electrodes, proves much more complicated to use in the case of liquid crystal cells, which, when they are of the matrix type, can comprise several hundred electrodes and counter-electrodes, which must each time be associated with a transfer electrical contact part. Of course, the manufacturing method could be automated, but the number and precision with which the electrical contact parts ought to be added onto the edge of the cells would considerably increase the manufacturing costs of such cells.

In order to overcome this problem, Patent documents JP 56 075624 and JP 56 168628 are known, which both disclose liquid crystal cells on the edge and back face of which conductive paths are deposited by printing.

Owing to these features, the display cell substrates can have substantially equal dimensions and do not need to be staggered with respect to each other to allow the electrical connections to be established between the electrodes and the control circuit. Thus, if, for the same external dimensions, the active surface of a liquid crystal cell can be increased, the display resolution can be increased, i.e. a larger number of line and column electrodes can be provided, without the pixel aperture, and thus the reflectivity of the display cell, being altered. Conversely, the increase in the display cell active surface, with a constant number of line and column electrodes, can be exploited to increase the width of said electrodes and thus the pixel aperture, which has a favourable effect on the reflectivity of the display.

The results described hereinbefore are attained owing to the fact that the means for connecting the electrodes of a display cell to a control circuit are not formed by contact parts which have to be individually bonded, but by conductive paths which allow the electrical contacts formed by the electrodes of a cell to be transferred from the edge of the cell to the back edge of said cell, then, from there, around said back edge and onto the back of the cell, these conductive paths being formed on the edge and the back of the cell by any appropriate technique for depositing and etching conductive layers in order to achieve the desired dimensions and resolution.

It might, however, be feared that the conductive paths, which are deposited in the form of thin layers, exhibit problems of reliability and electrical conduction continuity at the place where they match the often sharp back edge of the cell. In fact, the thermal stresses that appear during the cell manufacturing process can tear the conductive paths at the edge of the back substrate of the cell. Likewise, a thin layer deposited around the back edge of the cell has low mechanical strength and can easily be scratched and interrupted when the cell is handled or when one wishes to mount it in the portable object for which it is intended.

It is an object of the present invention to overcome the aforementioned problems in addition to others by providing a display device, particularly a liquid crystal cell, comprising means for connecting its electrodes to an electronic control circuit which are both simple to manufacture and reliable.

The present invention therefore concerns an electro-optical display cell, in particular a liquid crystal display, or an electrochemical photovoltaic cell, including:

- at least one transparent front substrate whose top surface forms the front face of the cell;

- at least one back substrate that may also be transparent or not, whose lower surface forms the back face of said cell;

- a sealing frame joining the front and back substrates and defining a volume for retaining an electro-optically or photo-electrically active medium in a sealed manner;

- said front and back substrates including on their faces opposite to each other at least one electrode each, these electrodes being intended to be connected by conductive paths to an electrical power or control circuit and defining lateral electric contact zones,

said cell being characterised in that the conductive paths are each formed of a first part in contact with the electrodes at the level of the lateral electric contact zones, and a second part extending over the back surface of the cell, contact means arranged continuously or discontinuously over the edge and/or the back of said cell

forming the electrical junction between the first and second parts of the conductive paths.

According to a variant, the contact means take the form of discrete bumps.

Thanks to these characteristics, conductive bumps are arranged on at least a part of the back periphery of the cell, so as to replace the arrangement of conductive paths around the back edge of the cell by a lateral contact pad on the opposite faces of the conductive bump that is more reliable and more resistant from a mechanical point of view.

In its most general acceptance, the present invention concerns a cell comprising a stack of (n) individual cells (where n is a natural integer number greater than or equal to 2), each of the individual cells being defined by two substrates belonging thereto, or a cell including (n+1) superposed substrates (where n is an integer number greater than or equal to 1), these (n+1) substrates being joined in pairs by a sealing frame.

The present invention also concerns a multi-layered liquid crystal display cell comprising four superposed substrates joined in pairs by sealing frames which each define a sealed cavity for retaining liquid crystals, a first sealing frame joining the first and second substrates, whereas a second sealing frame joins the second and third substrates and a third sealing frame joins the third and fourth substrates, said substrates including on their faces opposite each other at least one electrode each, said electrodes being intended to be connected by conductive paths to an electrical control circuit and defining lateral electric contact zones,

This cell being characterised in that the conductive paths extend continuously from the lateral electric contact zones to the back of the cell.

Other features and advantages of the present invention will appear more clearly from the following detailed description of an embodiment of a cell according to the invention, this example being given solely by way of non-limiting illustration, in conjunction with the annexed drawing, in which:

- Figure 1 is a general perspective view of a multi-layered liquid crystal display cell;

- Figure 2 is a general perspective view of the other side of the multi-layered cell shown in Figure 1;

- Figure 3 is a schematic, perspective and transparent view of a liquid crystal display cell including two substrates;

- Figure 4 is a longitudinal cross-section of the display cell shown in Figure 3;

- Figure 5 is a cross-section of a liquid crystal display cell according to the invention;

- Figure 6 is a cross-section of an alternative embodiment of the liquid crystal display cell shown in Figure 5;
- Figure 7 is a cross-section of another variant of the liquid crystal display cell shown in Figure 5;
- Figure 8 is a schematic view illustrating the method of metallising a liquid crystal cell according to the invention;
- Figure 9 is a cross-section of a liquid crystal cell according to the invention on the back of which a control circuit has been directly mounted;
- Figure 10 is a similar view to that of Figure 8, the control circuit being mounted on the back of the cell by means of a printed circuit board;
- Figure 11 is a similar view to that of Figure 8, the control circuit being mounted on the back of the cell by means of a flexible conductive film;
- Figure 12 is a similar view to that of Figure 9, an absorbent stress relaxation layer having been deposited on the back face of the cell, and
- Figure 13 is a perspective view of a liquid crystal cell provided with a strip of anisotropic conductive material forming the junction between the first and second parts of the conductive paths.

The present invention will be described with reference to a liquid crystal display cell. It goes without saying that the present invention is not limited to such a type of cell, and that it could apply to any type of cell including a sensitive medium capable of changing its physical properties, particularly its optical properties via application of a voltage, or its electrical properties via stress or radiation. In particular, the present invention applies to an electrochemical photovoltaic cell such as that described in International Patent Application No. WO 99/41638 in the name of the Applicant which is incorporated herein by reference.

Figures 1 and 2 are perspective views, respectively of the front and back of a multi-layered liquid crystal display cell. Designated as a whole by the general reference numeral 1, this display cell includes four superposed substrates 2, 4, 6 and 8, which may be made of glass or any other transparent material, such as plastic. It will be noted that the last substrate 8 may or may not be transparent, depending upon the reflecting or transmitting nature of display cell 1. In the present case, since an integrated display control circuit 10 is mounted on the back 12 of said cell 1 (see Figure 2), this is a reflective type cell and the back substrate 8 could be opaque or coated with an opacifier material in order to conceal or mask integrated circuit 10 from the view of an observer situated on the front side 14 of cell 1.

Substrates 2 to 8 are joined in pairs by sealing frames (not visible in Figures 1 and 2) which each define a sealed cavity for retaining liquid crystals. More specifically,

a first sealing frame joins substrates 2 and 4, whereas a second sealing frame joins substrates 4 and 6 and a third and final sealing frame joins substrates 6 and 8.

As will appear more clearly in the following description, the electrodes of cell 1 are flush with the edge 15 of cell 1 at distinct locations on its perimeter to define thereon lateral electric contact zones. Conductive paths 16 which come into contact with the electrodes at the lateral electric contact zones are formed directly on the edge 15 and the back 12 of cell 1, so as to transfer all of the electrical contacts onto the same back plane of said cell 1. Conductive paths 16 thus extend from the electrodes of cell 1 as far as the input port of integrated display control circuit 10 which is mounted on the back 12 of cell 1 via techniques that will be described in detail hereinafter. In Figures 1 and 2, it can be seen that the conductive paths are not of equal lengths and stop just at the locations where the electrodes are flush with the edge of the cell. It goes without saying that the conductive paths have been shown in order to facilitate comprehension of how the electrical connections are established between the electrodes and said conductive paths, but that, in practice, it is preferable to make conductive paths of equal lengths.

It is thus unnecessary to stagger the substrates of one cell in order to access the electrodes of the latter and establish the electrical connections with a power or control circuit. Thus, this peripheral surface, which is normally reserved for connecting the cell and which, proportionally, overlaps further onto the active surface of the cell, the smaller the cell is, can be omitted. This proves particularly advantageous when, for the same active surface of the cell, the number of line and column electrodes increases. In fact, in such case, the width of the electrodes decreases, and in order to keep the surface of the electrical contact pads constant, the electrodes would have to be lengthened, which would have the effect of increasing the non-active zone around the display cell.

Omitting the peripheral zone normally reserved for addressing a liquid crystal display cell not only allows the aspect ratio, between the active zones and non-active zones of such a cell to be improved. It also gets rid of a complex and cumbersome system of flexible printed circuits that are usually bonded onto the periphery of the cell and which connects the various control circuits that they carry to the electrodes of said cell.

Until now, a cell with several layers has been described, solely for the purpose of making it clear that the invention is not limited to cells including a single active layer, for example of liquid crystals. Nonetheless, for the sake of clarity, reference will be made hereinafter to a display cell including only two substrates which enclose between them a single liquid crystal layer.

Figure 3 is a schematic, perspective and transparent diagram of a liquid crystal cell 18 including two substrates 20 and 22, which can be made of glass or any other transparent material such as plastic. Substrates 20 and 22 are joined to each other by a sealing frame (see Figure 4 and following), which defines a sealed volume for retaining liquid crystals. Only two electrodes 24 and 26 have been shown in the drawing. It goes without saying, however, that in reality cell 18 includes a multiplicity of electrodes which are formed on the faces of substrates 20 and 22 which face each other. As can be seen, electrode 24 extends substantially over the total length of substrate 20 on which it has been deposited and at one of its ends, it is flush with edge 27 of said substrate 20 to define there a lateral electric contact zone 28. A conductive path 30 which is formed on edge 27 and on back 31 of cell 18 comes into contact with electrode 24 in contact zone 28, so as to transfer the electrical contact onto the back plane of said cell 18. The same is true of electrode 26, which defines a contact zone 32 where a conductive path 34 is formed.

Figure 4 is a longitudinal cross-section of liquid crystal cell 18 shown in Figure 3. This Figure shows sealing frame 36, which defines volume 38 for retaining the liquid crystal. Electrodes 24 and 26 pass underneath sealing frame 36 and are flush with edge 27 of substrate 20 on which they were formed to define the lateral electric contact zones respectively 28 and 32. Conductive paths 30 and 34 allow the electrical contacts formed by electrodes 24 and 26 of liquid crystal cell 18 to be moved from edge 27 of cell 18 to the edge or back rim 40 of said cell, then, from there, around said back edge 40 and to back 31 of cell 18.

Conductive paths 30 and 34 are formed by depositing thin layers of an electrically conductive material as will be described in detail hereinafter. Consequently, one might fear that the conductive paths exhibit problems of resistance to heat and to mechanical stresses and might tear at the places where they match the often sharp back edge 40 of the cell during manufacture of the cell or when it is handeld. This is why, according to the embodiment illustrated in Figures 5 and 6, conductive bumps 42 are formed along back edge 40 of the cell to ensure the continuity of conductive paths 30 and 34.

Indeed, as is visible in Figure 5, conductive paths 30 and 34 are each made up of a first part, respectively 30a and 34a, which extends over at least part of edge 27 of cell 18, and a second part, respectively 30b and 34b, which extends over at least a part of back 31 of cell 18, conductive bumps 42 forming the electric junction between the first ands second parts of said conductive paths 30 and 34. More specifically, the first parts 30a and 34a of conductive paths 30 and 34 come into contact laterally with conductive bumps 42, whereas the second parts 30b and 34b of said conductive

paths 30 and 34 can extend as far as the top of said bumps 42 and even cover them partially. Consequently, the arrangement of conductive paths 30 and 34 around back edge 40 of cell 18 is replaced by lateral contact on opposite faces 44 and 46 of conductive bumps 42.

According to a variant shown in Figure 6, the second parts 30b, 34b of conductive paths 30 and 34 extend at least partially underneath conductive bumps 42.

According to another variant shown in Figure 7, at least some of bumps 42 can be arranged on edge 27 of cell 18.

In order to form the conductive paths which allow the electrical contacts formed by the electrodes of one cell to be moved to the back of the latter, one proceeds as follows. A fine layer of conductive material is evaporated onto the back of the cells while the latter are still in a batch. After the cells have been separated, a group of them is arranged on a support or fitting 48 (see Figure 8). The cells are arranged parallel to each other obliquely and slightly staggered in relation to each other, such that their large sides 50 are parallel and their small sides 52 which will be metallized are arranged in a staggered staircase. An evaporation source 54 of an electrically conductive material is arranged facing fitting 48, opposite edges 52 of the cells to be metallized.

After back 31 and edge 27 of the cells have been metallized, the conductive paths have to be structured, for example by laser ablation. For the sake of economy and in order to obtain a better yield, only first parts 30a, 34a of conductive paths 30, 34 which extends over edge 27 of liquid crystal cells 18 will be structured by laser ablation, whereas second parts 30b, 34b of the same conductive paths 30, 34 which extend to back 31 of cells 18 will be structured by conventional photolithographic techniques.

Reference will now be made to Figure 9 in which it can be seen that an integrated display control circuit 56 is mounted directly on back 31 of display cell 18. In the example shown in the drawing, integrated circuit 56 is flip chip bonded on display cell 18, such that its input ports 58 are bonded onto conductive paths 30, 34 of cell 18. Of course, according to a variant, input ports 58 of integrated circuit 56 could be connected to conductive paths 30, 34 by fine conductive wires, or wire bonding.

Thus, owing to these features, all of the operations for securing the integrated display control circuit occur in the same working plane, namely the back face 31 of the display cell, which considerably simplifies the manufacture of such an assembly. It will be noted, moreover, that display cell 18 provides control circuit 56 with a very stable mechanical support. It will be noted finally that, owing to the invention, it is possible to use only one integrated circuit to control both the line and column electrodes.

According to a variant of the invention shown in Figure 10, integrated control circuit 56 is mounted on the back 31 of liquid crystal display cell 18 not directly, but via a printed circuit board 60.

According to yet another variant of the invention shown in Figure 11, the integrated control circuit 56 is mounted on the back 31 of liquid crystal display cell 18 via a flexible conductive film 61 made of Kapton®, a technique known as tape automatic bonding or TAB.

It goes without saying that the present invention is not limited to the embodiments that have just been described and that various simple alterations and variants can be envisaged without departing from the scope of the present invention. In particular, one could envisage (see Figure 12) depositing, on the back of the liquid crystal cell, a transparent or coloured absorbent layer 62, whose functions would be as follows:

- absorbing the light transmitted through the liquid crystal cell;
- acting as a relaxation layer for the thermo-mechanical stresses which appear between the glass back substrate and the conductive paths during high temperature assembly of the control circuit on said back substrate;
- protecting the cell, and in particular the liquid crystal, from radiation by the laser beam during structuring of the metallic paths.

The absorbent layer should also be able to resist chemical etching baths when the metallic layer is etched on the back of the cell.

One could also envisage (see Figure 13) replacing the individual conductive bumps by a tape of anistropic conductive material 64, which would only lead the current along direction of the depth of the tape, i.e. from back edge 40 of cell 18 towards the centre of the latter and not transversely, to avoid any risk of short-circuiting two adjacent conductive paths.